# A general equilibrium ecology/economy model applied to an Alaskan marine system


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The economics discipline has demonstrated a growing awareness of the vital role ecosystems occupy in economic activity. Two themes run through the literature.

1. ecosystems and economies are jointly determined,

   Daly (1968), Crocker and Tschirhart (1992), Brown and Roughgarden (1995), Nordhaus and Kokkelenberg (1999), Settle and Shogren (2002), Carpenter et al. (1999), Brock and Xepapadeas (2003), Tilman et al. (2003).

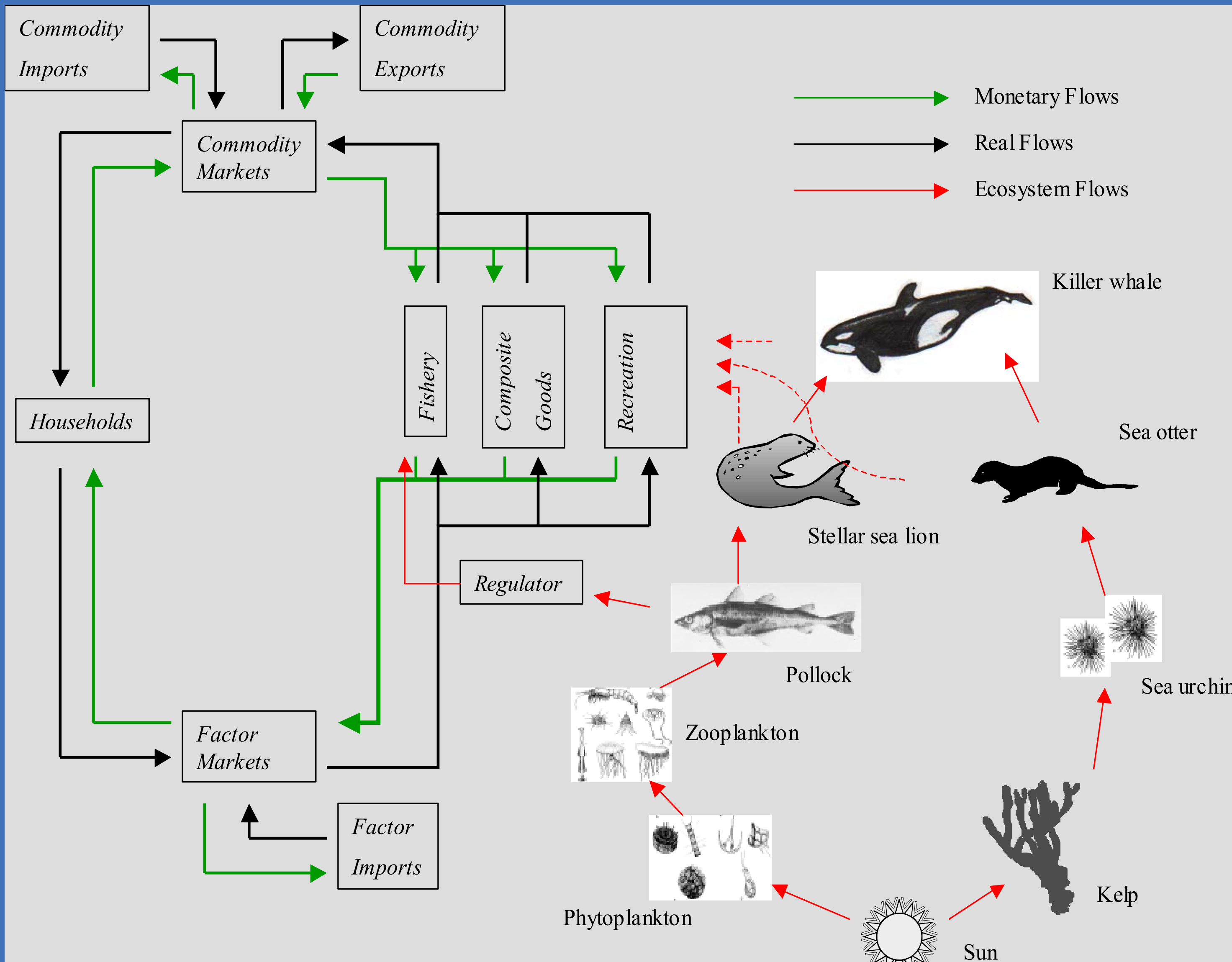
And

2. ecosystems and economies are complex, adaptive systems

   Kokoski and Smith (1987), Arrow et al. (2000), Levin (1998)

# Economy and Ecosystem Analogies

| Economy | Ecosystem |
|---|---|
| industries | species |
| firms | individual plants and animals |
| maximize profits | maximize net energies |
| quantities | biomasses |
| prices | energy prices |
| firms demand inputs | predators demand biomass |
| firms supply outputs | prey supplies biomass |
| market exchange | biomass transfers |
| macro outcomes | population densities |


Commodity Imports
Commodity Exports
Monetary Flows
Real Flows
Ecosystem Flows
Commodity Markets
Fishery
Composite Goods
Recreation
Killer whale
Sea otter
Households
Stellar sea lion
Regulator
Pollock
Sea urchin
Zooplankton
Factor Markets
Factor Imports
Kelp
Phytoplankton
Sun

# Three basic equations in GEEM:

1) net energy

$$R_i = \sum_{j=1}^{i-1} [e_j - e_{ij}] x_{ij} - \sum_{k=i+1}^{m} e_i [1 + t_i e_{ki}] y_{ik} (\sum_{j=1}^{i-1} x_{ij}) - f^i (\sum_{j=1}^{i-1} x_{ij}) - \beta_i$$

2) biomass transfers (similar to market clearing)

$$N_i x_{ij}(\mathbf{e}_i) = N_j y_{ji}(\boldsymbol{x}_j(\mathbf{e}_j))$$

3) population updating

$$N_i^{t+1} = N_i^t + N_i^t \frac{1}{s_i} [\frac{R_i(\cdot) + v_i}{v_i^{ss}} - 1]$$

## Regulated Fishery

$$TAC_t = a + bN_4^{0,t}$$ -- total allowable catch is set

$$H_F = d_F T^{a_F} N_4$$ -- harvest depends on time and fish

minimize $\hat{w}L_F + \hat{r}K_F$ -- minimize cost of time fishing

subject to $T = d_F^m L_F^{a_F^m} K_F^{(1-a_F^m)}$

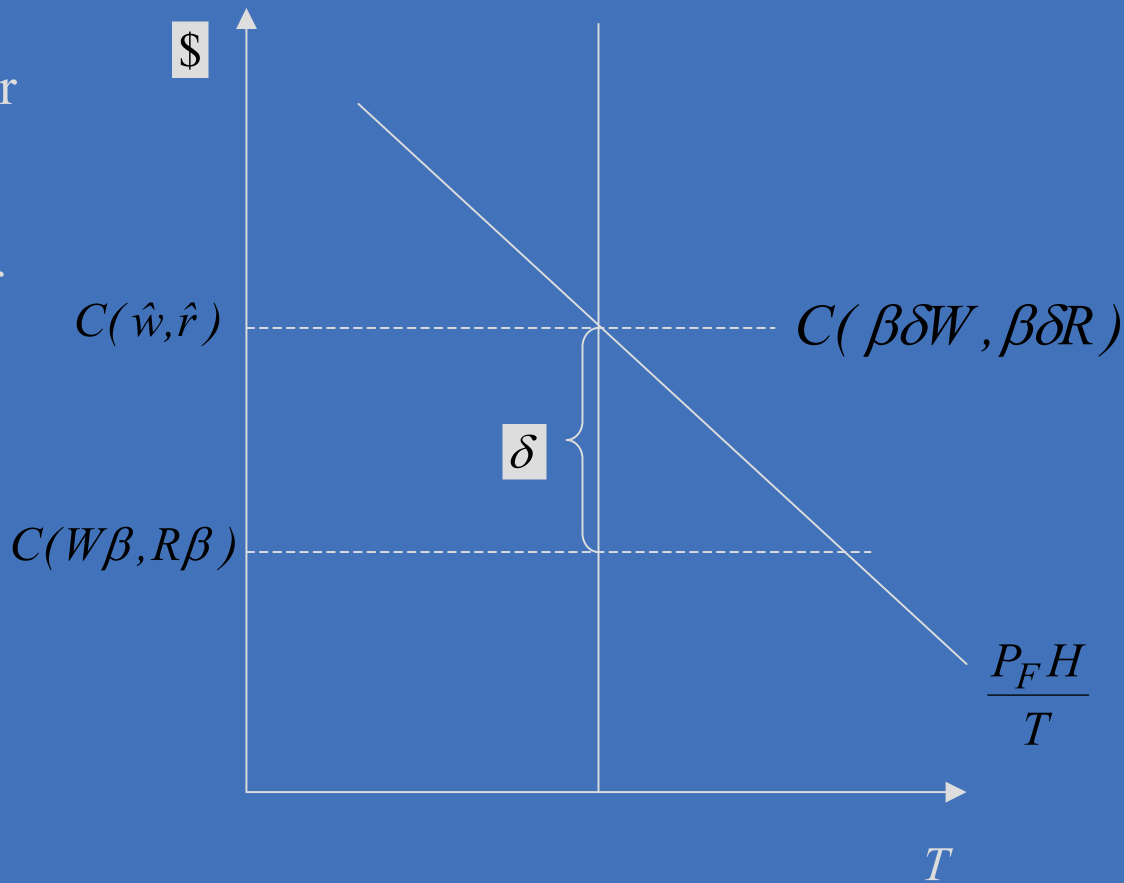
Time is likely to be less than one year which gives rise to factor compensating differentials.

# Compensating differentials

$\hat{w} = \beta\delta W$ *where* $\delta = 1 \Rightarrow$ *no comp diffs and* $\delta > 1 \Rightarrow$ *positive comp diffs*

$\beta$ - accounts for season length

$\delta$ - accounts for comps diffs




$$\pi_F = P_F H_F - C(\beta\delta W, \beta\delta R)T = 0$$

# Welfare Measures

$$I^i = earned\ income - savings + \begin{cases} unearned\ labor\ income\ at\ 100\%\ W \\ unearned\ labor\ income\ at\ 75\%\ W \\ unearned\ labor\ income\ at\ 50\%\ W \end{cases}$$

$$EV = M(\underline{P}^b, V^a(\underline{P}^a, I^a)) - M(\underline{P}^b, V^b(\underline{P}^b, I^b))$$

# Labor Market

$$labor \quad payments \quad =$$

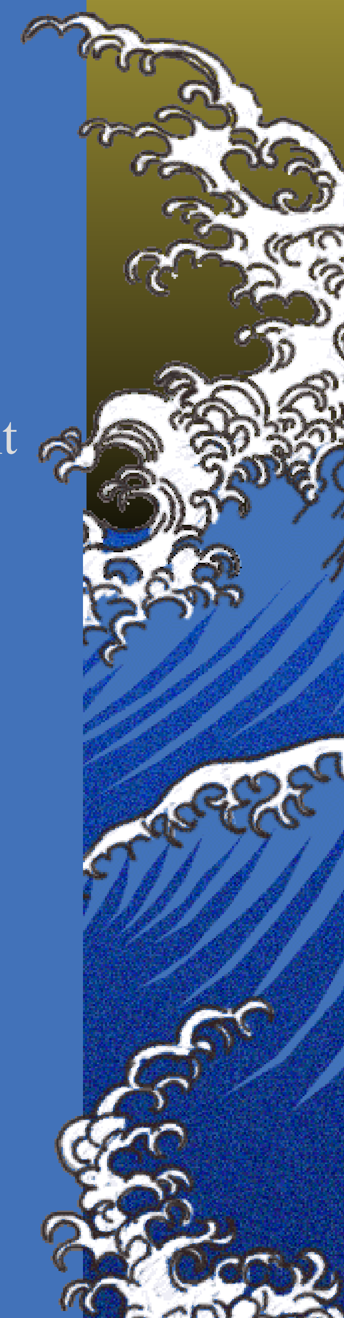
$$\hat{w} L_F(T,\hat{w}) \quad + \quad vL_F(T,\hat{w})(1-\beta) \quad + \quad W[\bar{L} - L_F(T,\hat{w})]$$

$$\frac{\Delta L_F}{\Delta T} = \frac{\Delta L}{\Delta T} + \frac{\Delta L}{\Delta \hat{w}} W \frac{\Delta \delta}{\Delta T} > 0$$

$T$ = season length
$v$ = leisure payment
$\beta$ = % of season
$\delta$ = comp. diff.

$$\frac{\Delta\begin{pmatrix} labor \\ payments \end{pmatrix}}{\Delta T} = W\delta(T)\beta(T)\underset{+}{\frac{\Delta L_F}{\Delta T}} + L_F(\cdot)W[\delta\underset{-}{\frac{\Delta \delta}{\Delta T}} + \beta\underset{+}{\frac{\Delta \beta}{\Delta T}}]$$

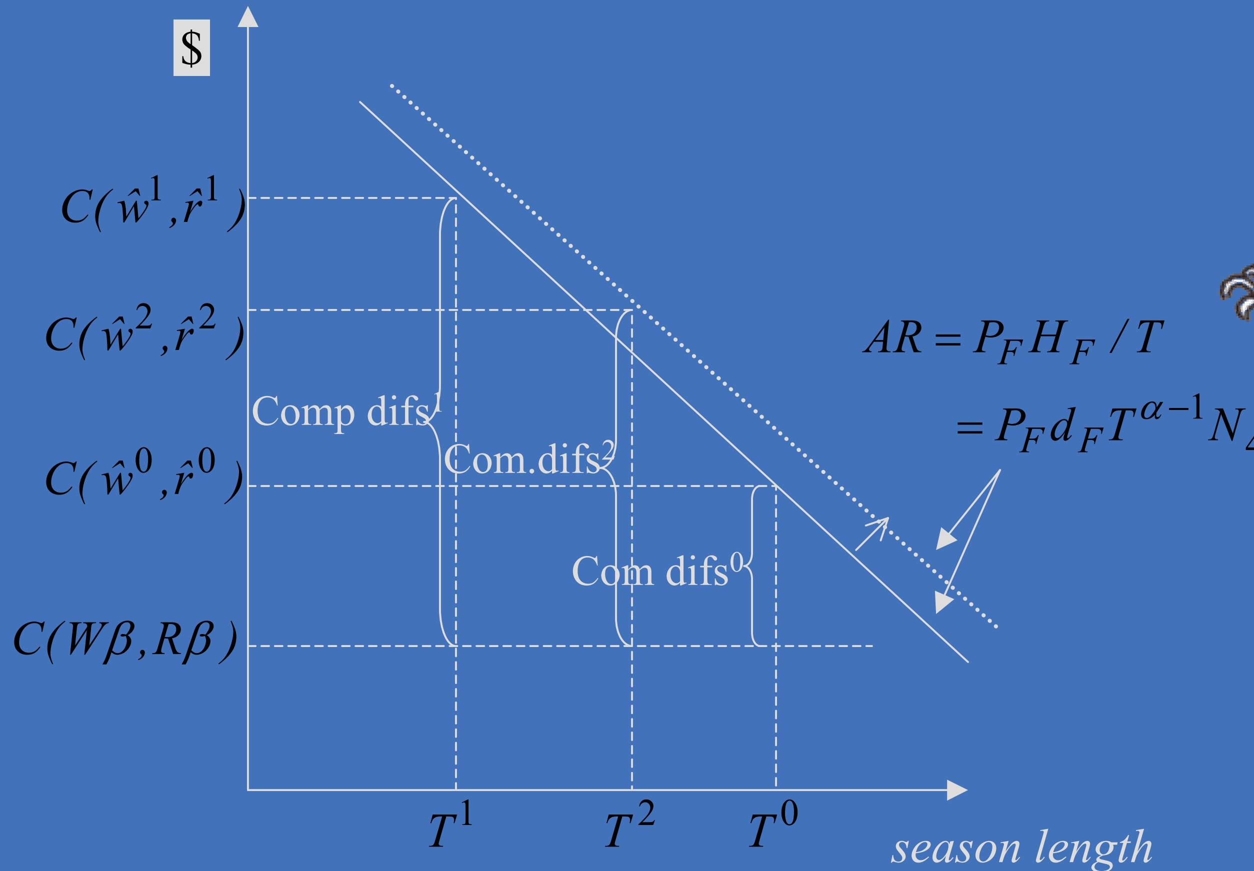
$$- vL_F(\cdot)\underset{+}{\frac{\Delta \beta}{\Delta T}} + v(1-\underset{+}{\beta})\underset{+}{\frac{\Delta L_F}{\Delta T}} - W\underset{+}{\frac{\Delta L_F}{\Delta T}}$$



# Compensating Diffs and Harvests

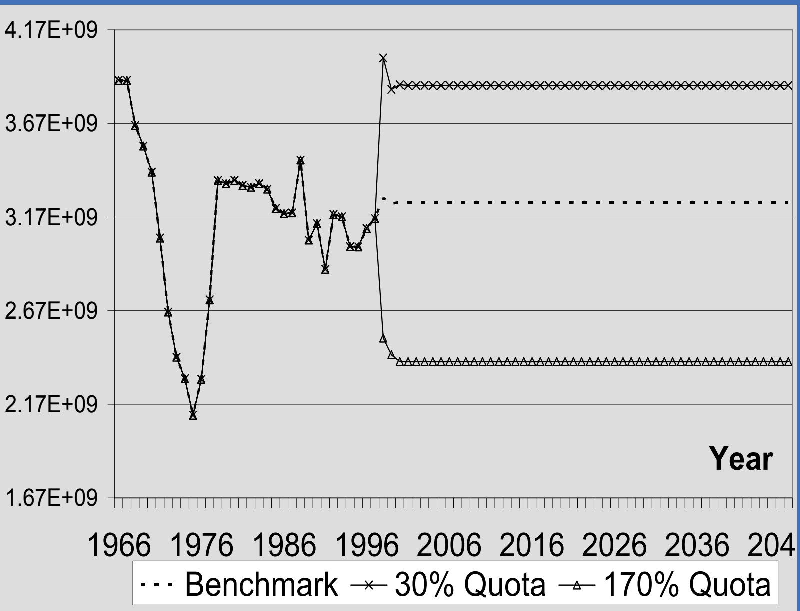
$\beta$- accounts for season length

$\delta$- accounts for comp diffs

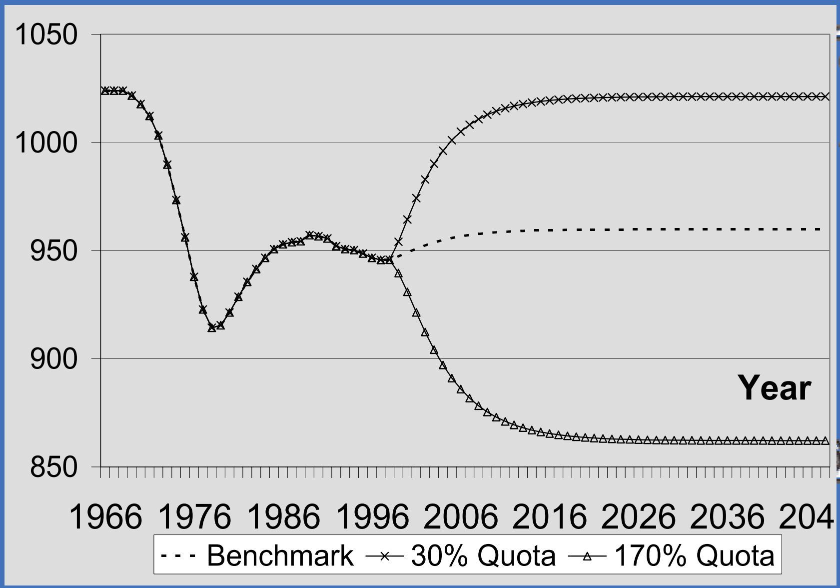



$$\pi_F = P_F H_F - C(\beta\delta W, \beta\delta R)T = 0$$

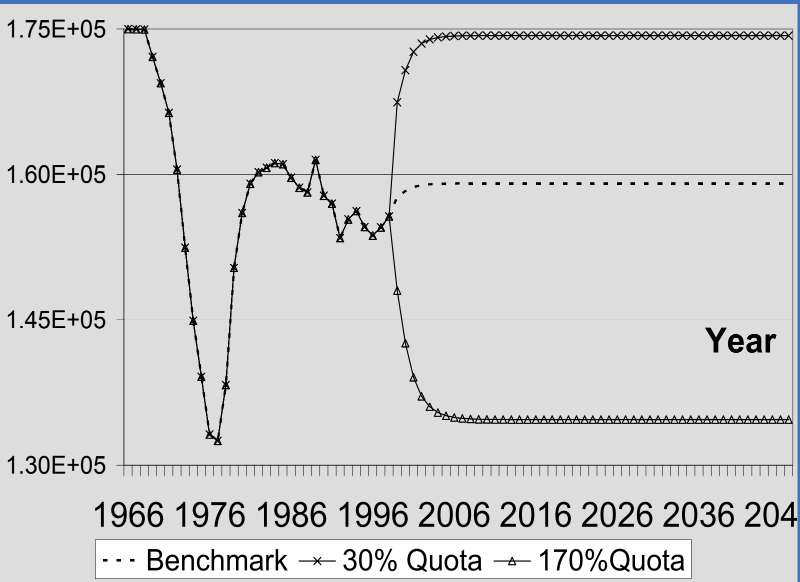
# Pollock



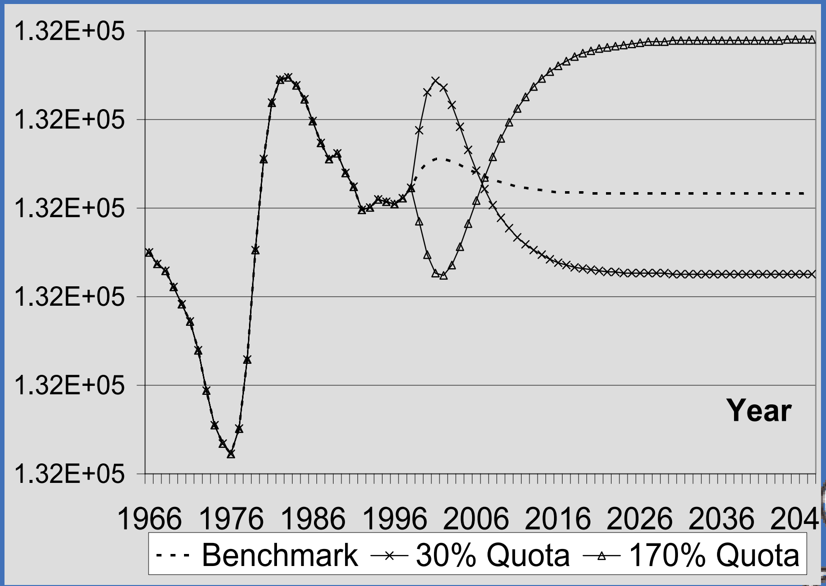

# Killer Whale



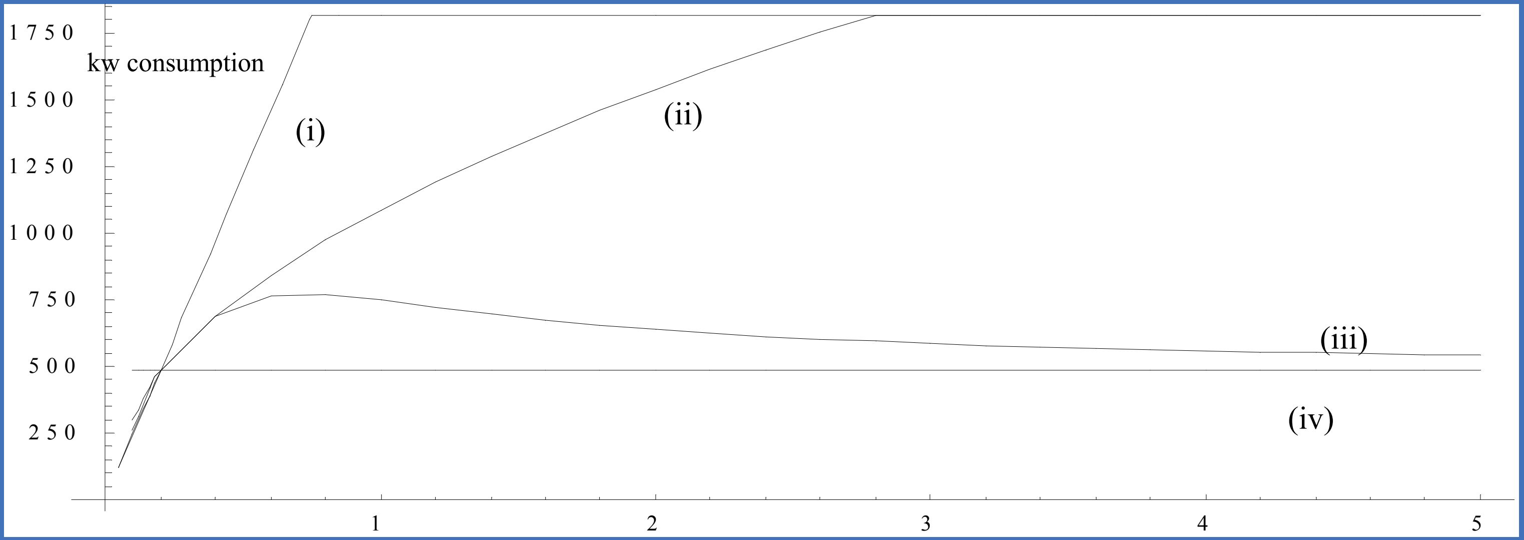

# Sea Lion

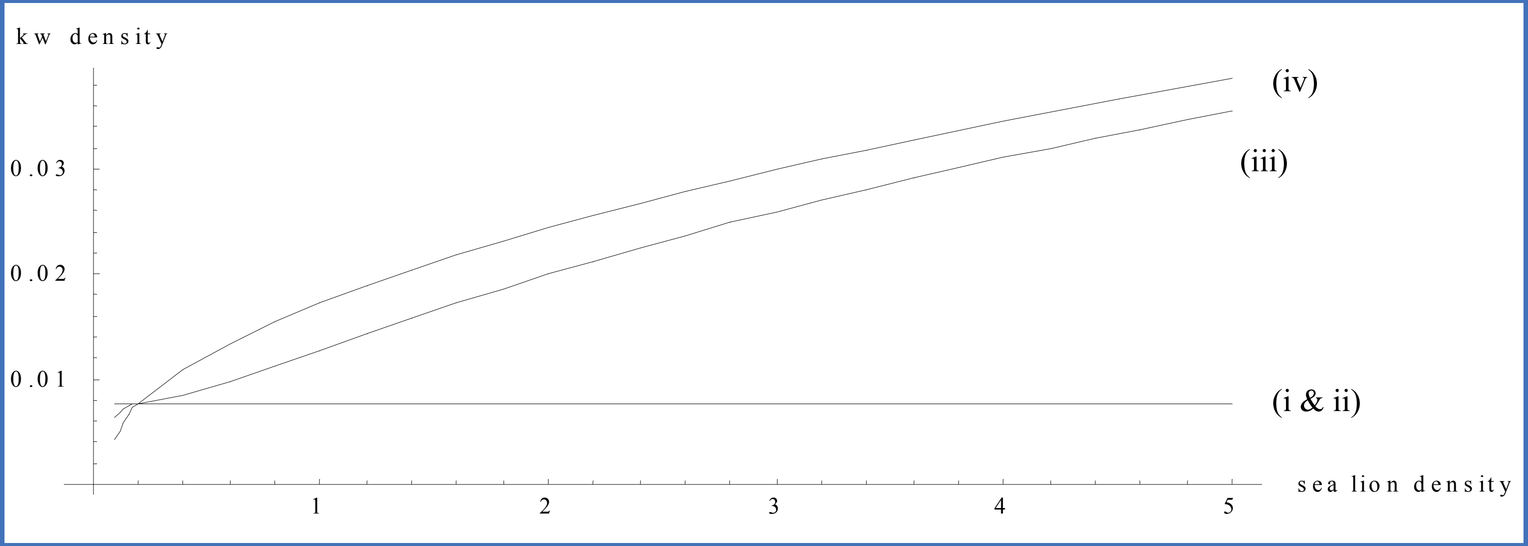



# Otter



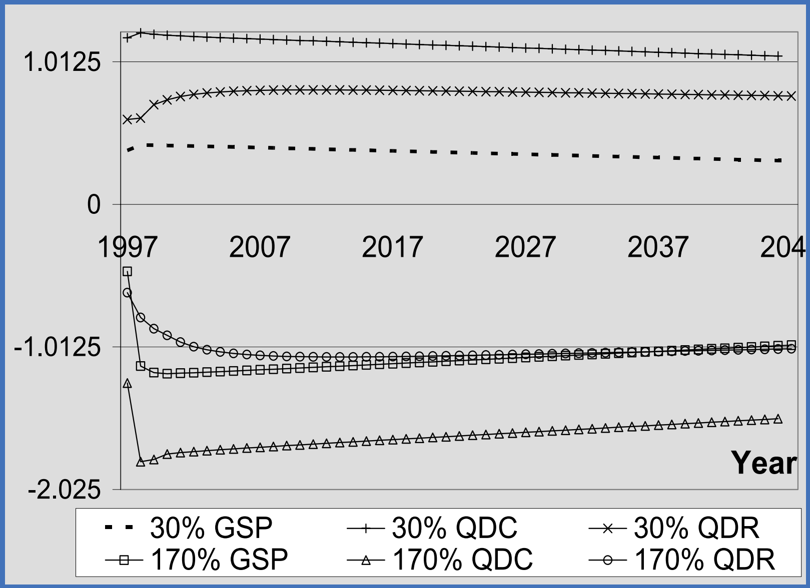

Populations


kw consumption
1750
1500
1250
1000
750
500
250
(i)
(ii)
(iii)
(iv)
1
2
3
4
5

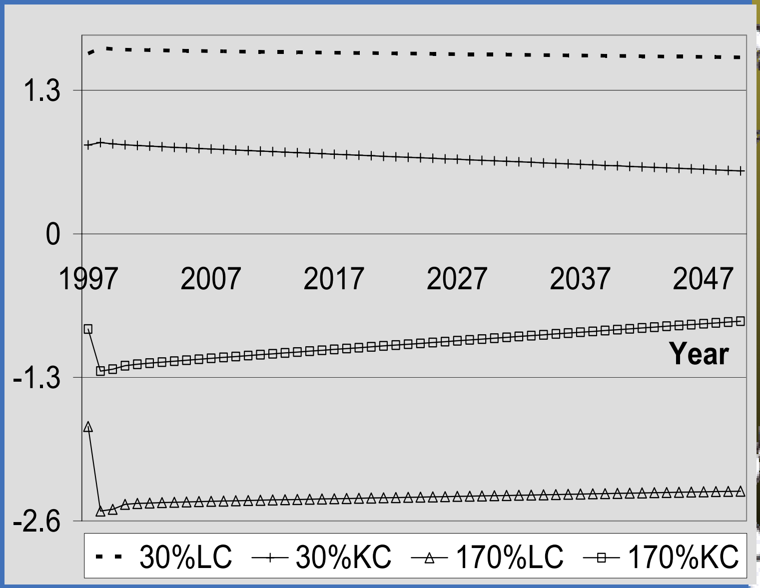

kw density
0.03
0.02
0.01
(iv)
(iii)
(i & ii)
sea lion density
1
2
3
4
5

% Change From Baseline

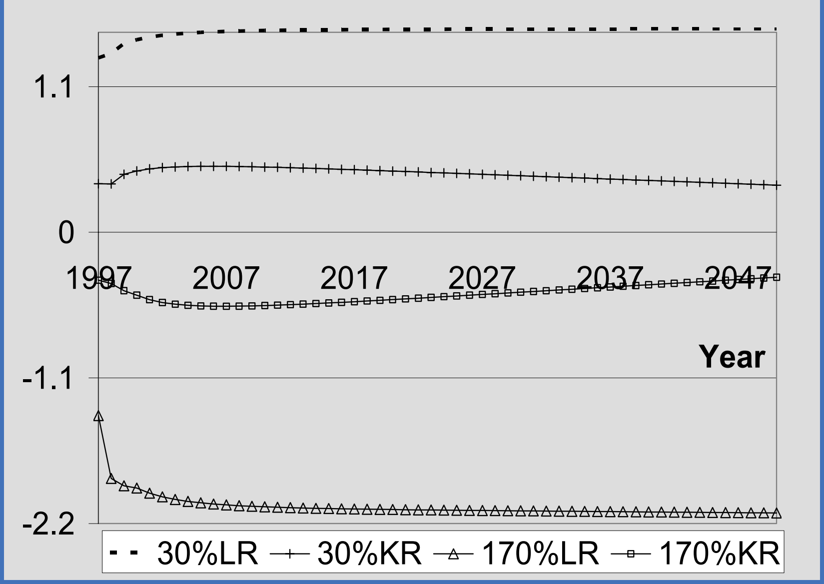
## Regional Production



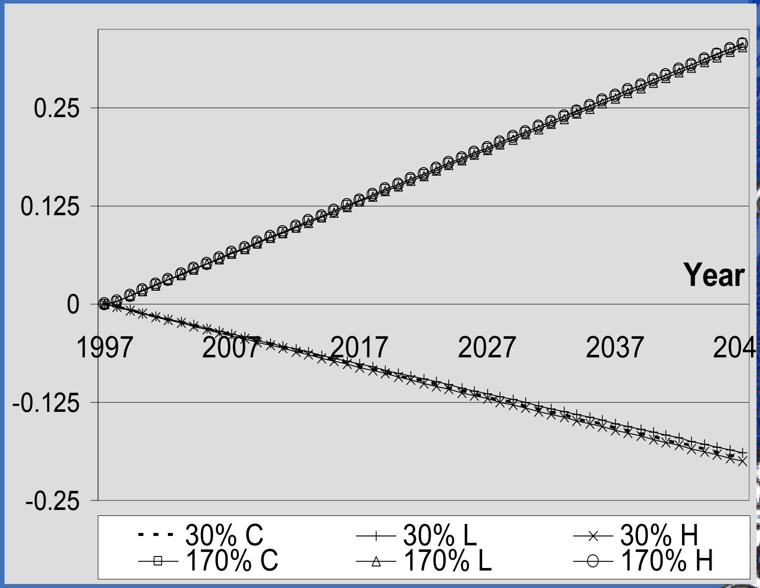

## Composite Factor Employment




## Recreation Factor Employment




## Regional Capital Stock



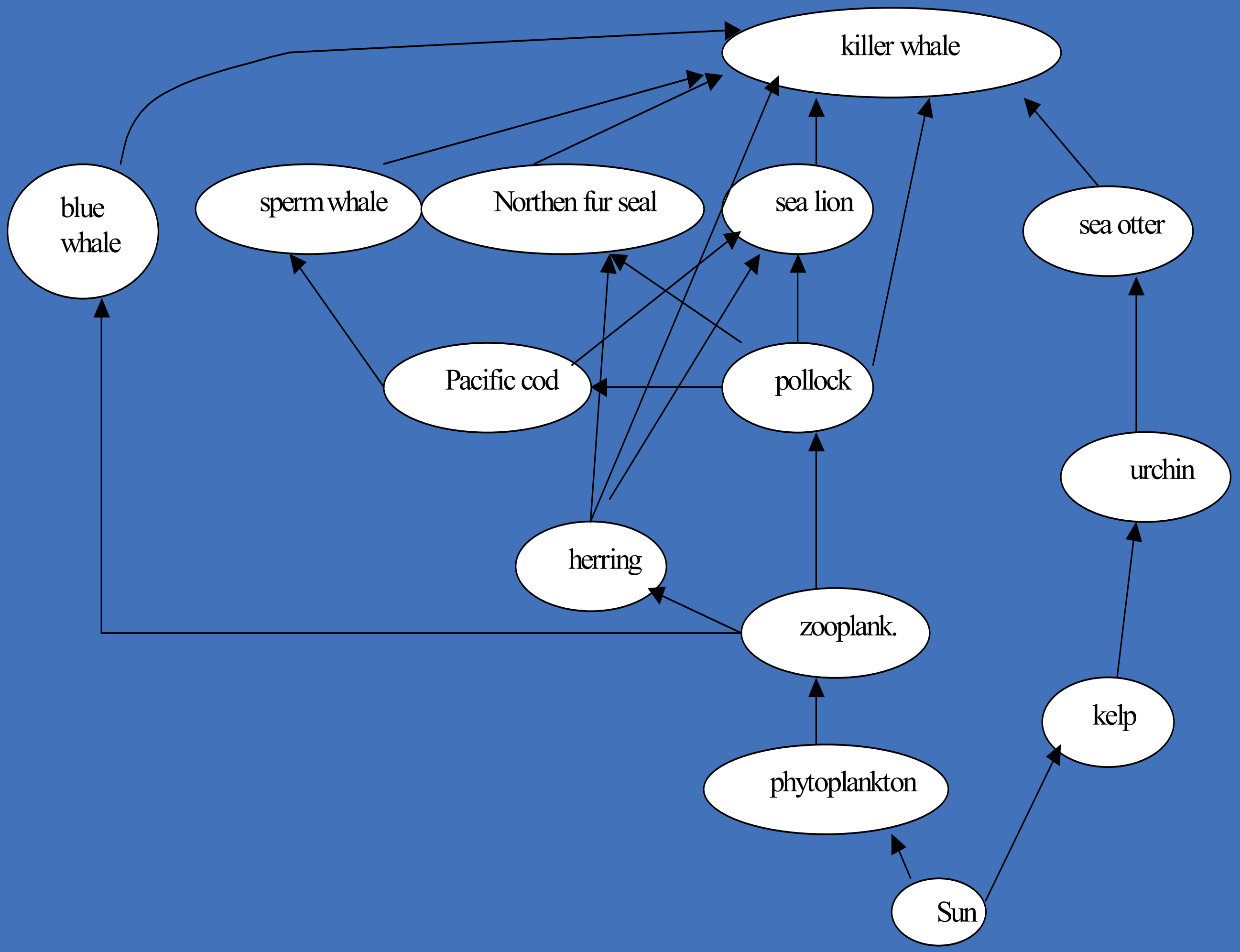
# Cumulative Welfare Impacts

| *Unearned Labor Income (% of Wage Rate)* | *Quota Rule* | *50 Year Horizon (Million 1997 $)* | *100 Year Horizon (Million 1997 $)* |
|---|---|---|---|
| *100%* | *30%* | *$1118* | *$1211* |
| | *170%* | *-$7811* | *-$8665* |
| *75%* | *30%* | *$1530* | *$1674* |
| | *170%* | *-$7335* | *-$8129* |
| *50%* | *30%* | *$1943* | *$2139* |
| | *170%* | *-$6859* | *-$7593* |

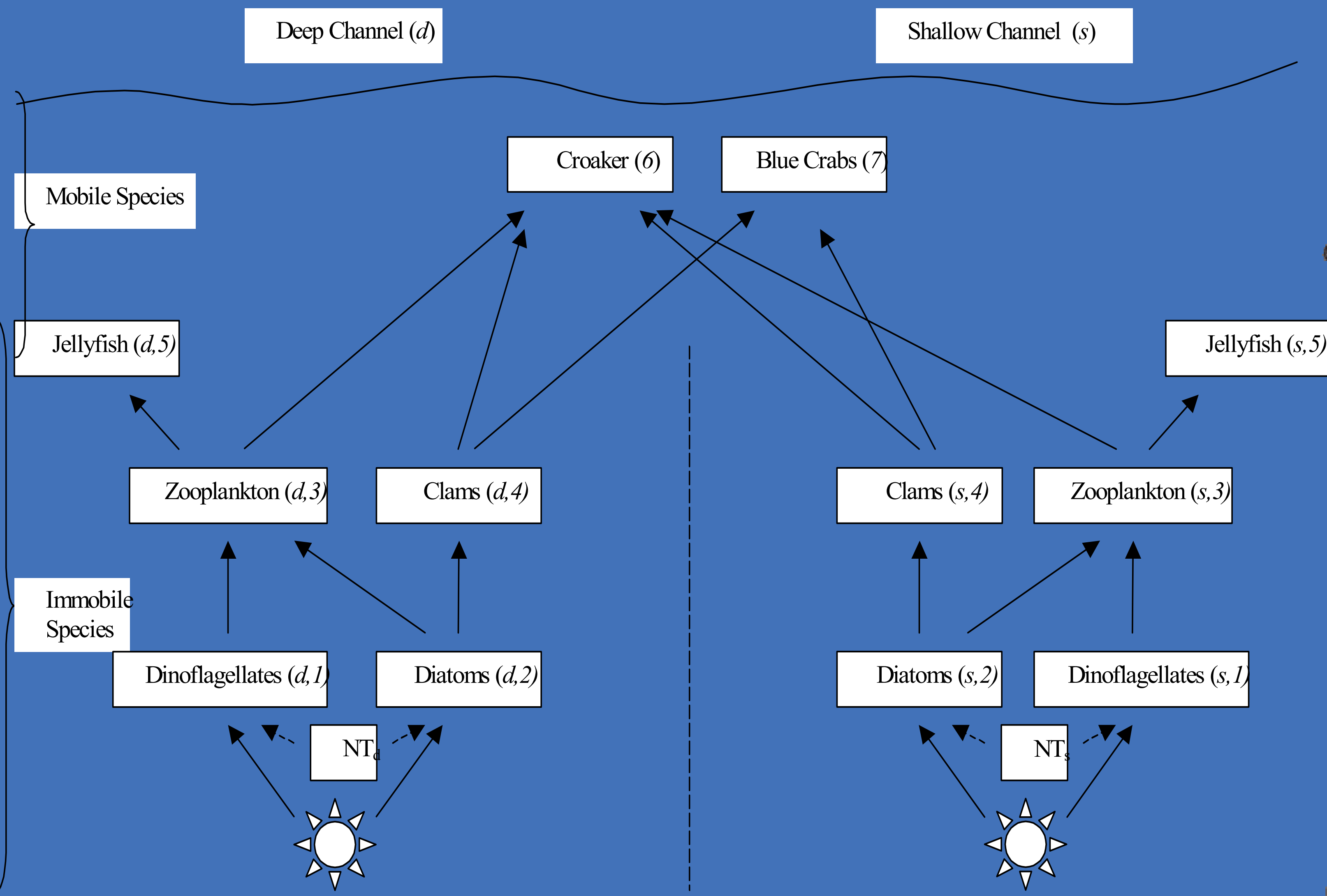
## Direct Ecosystem Valuation Per Percentage Change in Ecosystem Inputs

| *Unearned Labor Income (% of Wage Rate)* | *Quota Rule* | *Average Annual Welfare Change Per 1 % Change in Ecosystem Inputs: Linked Model – Non-Linked (1997 $)* |
|---|---|---|
| *100%* | *30%* | *$109,626* |
| | *170%* | *$114,458* |
| *75%* | *30%* | *$109,677* |
| | *170%* | *$114,493* |
| *50%* | *30%* | *$109,728* |
| | *170%* | *$114,529* |

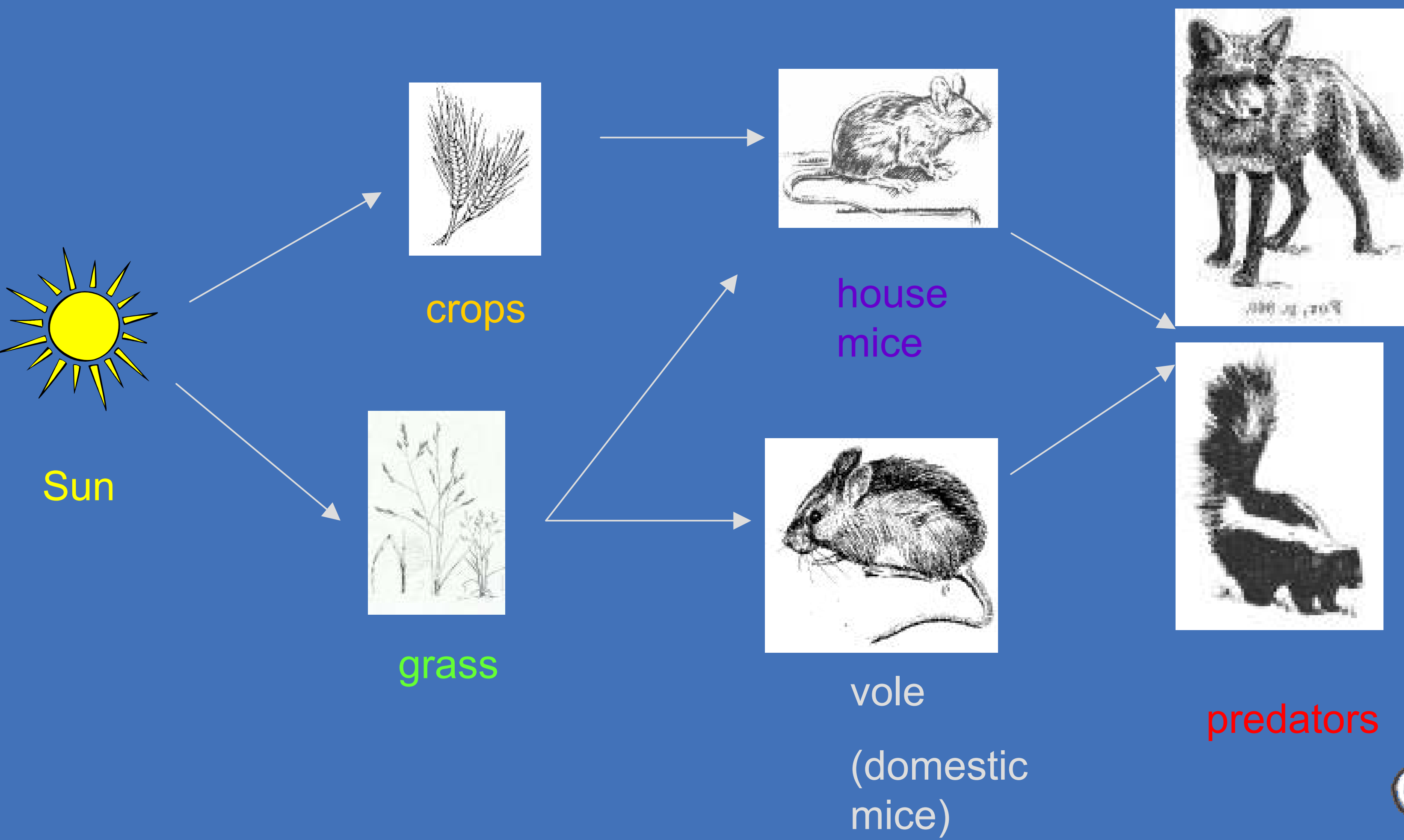
# Expanded Ecosystem



# Neuse Estuary



# Kern County Ecosystem



# Conclusions

***Point: Integrate models so that policies directed to either system, but which inevitably affect the other system, are better informed.***

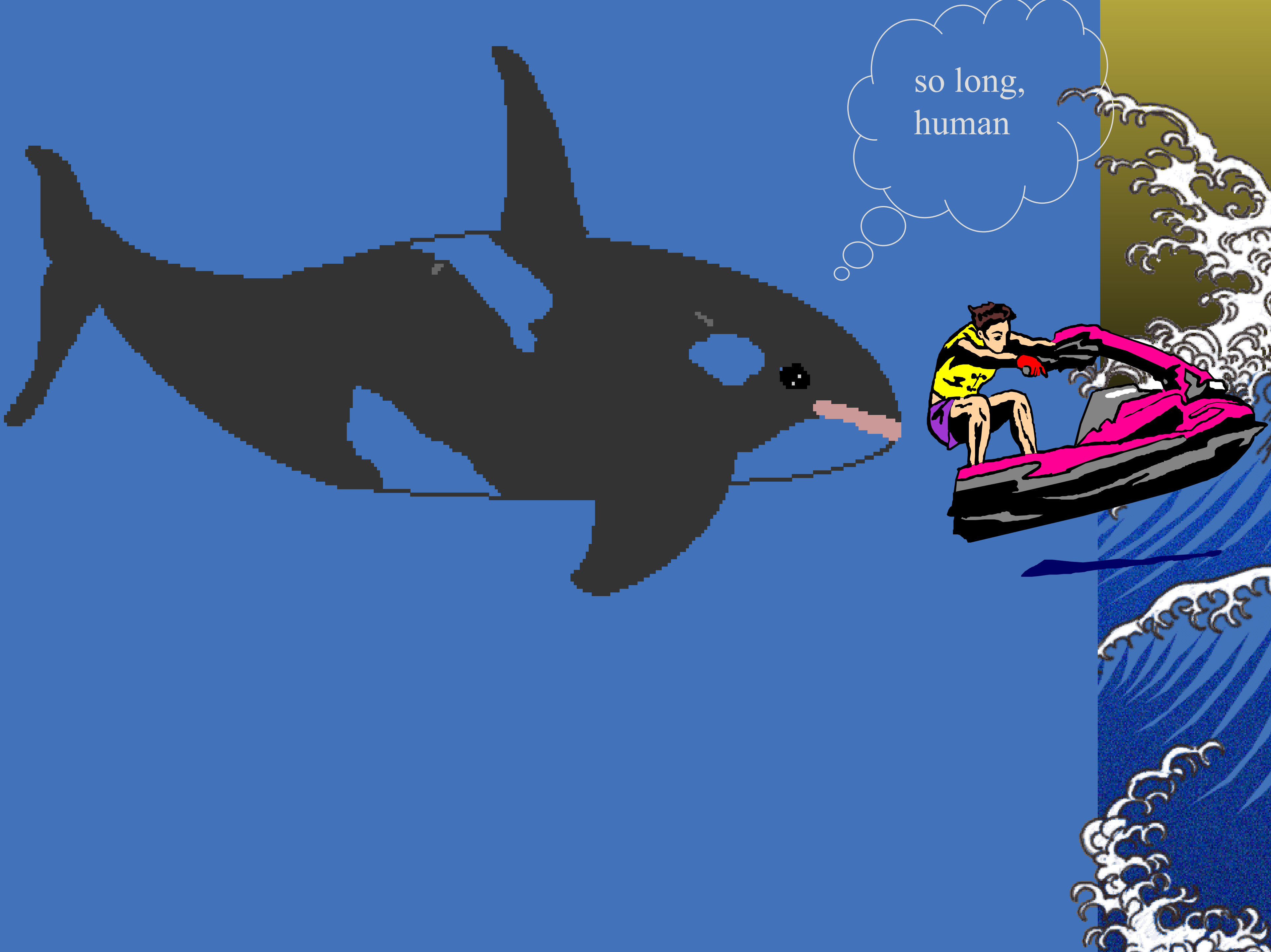
*Although ecosystems provide myriad services to economies, only one service is considered in most economic renewable resource models*

*Measures of ecosystem health are given by species populations, and measures of economic health are quantified*

*Results are a clear demonstration of the joint determination of human and natural systems*

*We quantify welfare consequences of ignoring ecosystem response*

*Mediating behavior of both systems to shocks arising from the other is integral to meaningful policy analysis*


so long,
human